Chapter 8

1. (b) $30^\circ \times 2\pi/360^\circ = \pi/6 = 0.524$ rad

   (b) $90^\circ \times 2\pi/360^\circ = \pi/2 = 1.57$ rad

   (c) $420^\circ \times 2\pi/360^\circ = 7\pi/3 = 7.33$ rad

2. $\tan 6^\circ = .300$ km/x
   $x = 2.85$ km

3. $d = (3.8 \times 10^5 \text{ km})(1.8 \times 10^{-5} \text{ rad}) = 6.8$ km

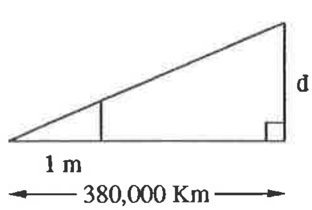
4. $\omega = 2\pi f = 2\pi(2000 \text{ r.p.m.})/(60 \text{ s/m}) = 209$ rad/s.

5. $v = r\omega = (0.1 \text{ m})(209 \text{ rad/s}) = 21$ m/s.

6. $\alpha = \omega t = 2\pi(33 \text{ r.p.m.})/(60 \text{ s/m})/(2.8 \text{ s}) = 1.23 \text{ rad/s}^2$.

7. $\omega_0 = 2\pi f = 2\pi(1200 \text{ r.p.m.})/(60 \text{ s/m}) = 126$ rad/s. $0 = \omega_0 + \alpha t$.
   Hence $\alpha = (126 \text{ rad/s})/(15 \text{ s}) = -8.4 \text{ rad/s}^2$.

8. $7000 \text{ m}/[\pi(0.68 \text{ m})] = 3280$ revolutions

9. 

   The angular measure of the moon $d/(3.8 \times 10^8 \text{ m}) = (0.009/1 \text{ m})$, i.e. a penny held at arms length will blot out the moon. $d = 3.4 \times 10^6$ m. $\theta \simeq .5^\circ$

10. (a) $\omega = (2\pi/T) = 2\pi/1 \text{ yr} = 2\pi/(3.15 \times 10^7 \text{ s}) = \underline{1.99 \times 10^{-7} \text{ rad/s}}$.

(b) $\omega = (2\pi/T) = 2\pi/1 \text{ day} = \underline{7.27 \times 10^{-5} \text{ rad/s}}$.

11. (a) $v = r\omega = (6.37 \times 10^6 \text{ m})(7.27 \times 10^{-5} \text{ rad/s}) = \underline{464 \text{ m/s}}$.

(b) $v = (6.38 \times 10^6 \text{ m})(\cos 60^\circ)(7.27 \times 10^{-5} \text{ rad/s}) = \underline{232 \text{ m/s}}$.

12. $r\omega^2 = 10^5 g$. $\omega = (10^5\, g/r)^{\frac{1}{2}} = ((10^5)(9.8)/(0.9))^{\frac{1}{2}} = 3.3 \times 10^3 \text{ rad/s}$.
Centrifuge must rotate at $(3.3 \times 10^3 \text{ rad/s})/(2\pi \text{ rad/rev}) \cdot (60 \text{ s/min}) = 3.15 \times 10^4$ r.p.m.
$= \underline{3.2 \times 10^4 \text{ r.p.m.}}$

13. 300 r.p.m. $\equiv 10\pi$ rad/sec

(a) 200 r.p.m. $\equiv \dfrac{20\pi}{3}$ rad/sec.

Use $\omega = \omega_0 + \alpha t$.

$10\pi \text{ rad/s} = \dfrac{20\pi}{3} \text{ rad/s} + \alpha(3 \text{ s})$

$\alpha = \underline{3.49 \text{ rad/sec}^2}$

(b) $a_r = r\omega^2$

After 2s, $\omega = \dfrac{20\pi}{3} \text{ rad/sec} + 3.49 \text{ rad/sec}^2 \times 2\text{s}$

$\omega = 27.9 \text{ rad/sec}^2$
$a_r = (0.30 \text{ m})(27.9 \text{ rad/s})^2 = \underline{230 \text{ m/s}^2}$
$a_T = r\alpha = (0.3 \text{ m})(3.49 \text{ rad/s}^2)^2$
$a_T = \underline{1.05 \text{ m/s}^2}$

14. At point of contact, $v_1 = v_2$.
So $r_1\omega_1 = r_2\omega_2$
$\omega_1/\omega_2 = \underline{r_2/r_1}$

15. $\omega^2 = \omega_0^2 + 2\alpha\theta$.
$(3.46)^2 = 2\alpha(2\pi)(2.5)$.
$\alpha = \underline{0.38 \text{ rad/s}^2}$

16. $\alpha = \omega/t = 1047/270 = 3.88 \text{ rad/s}^2$
$\theta/(2\pi \text{ rad/rev}) = \alpha t^2/4\pi = (3.88 \text{ rad/s}^2)(270 \text{ s})^2/(4\pi \text{ rad/rev}) = \underline{2.25 \times 10^4 \text{ rev}}$

17. (a) 1000 r.p.m. = 104.7 rad/s; 3600 r.p.m. = 377.0 rad/s
α = [(104.7 rad/s) − (377.0 rad/s)]/(5.0 s) = $\underline{-54\ \text{rad/s}^2}$

(b) $\theta = (377.0\ \text{rad/s})(5.0\ \text{s}) + \frac{1}{2}(-54.4\ \text{rad/s}^2)(5.0\ \text{s})^2 = 1204\ \text{rad} = \underline{190\ \text{rev}} = \underline{1.9 \times 10^2\ \text{rev}}$

18. $s = r\theta = r(w + w_0)t/2$ = (0.35)[(480 r.p.m.)(2π rad/rev)/(60 s/min)](5.5)/2]
= $\underline{48.4\ \text{m}}$ = $\underline{48\ \text{m}}$

19. $v = v_0 + at$.
Divide by r; $\omega = \omega_0 + \alpha t$. $x = v_0 t + at^2/2$.
Divide by r; $\theta = \omega_0 t + \alpha t^2/2$. $v^2 = v_0^2 + 2ax$.
Divide by r^2; $\omega^2 = \omega_0^2 + 2\alpha\theta$. $\bar{v} = (v + v_0)/2$.
Divide by r; $\bar{\omega} = (\omega + \omega_0)/2$.

20. 33 r.p.m = 3.46 rad/s.
Linear tangential speed required = $r\omega$ = (0.05 m)(3.46 rad/s) = 0.173 m/s.
Thus first wheel must attain ω = (0.173 m/s)/(0.03 m) = 5.77 rad/s.

(a) Use $\omega = \omega_0 + \alpha t$; (5.77 rad/s) = (0.88 rad/s²)t. t = $\underline{6.55\ \text{s}}$.

(b) $r_1\alpha_1 = r_2\alpha_2$, α_2 = (0.88 rad/s²)(3/5) = $\underline{0.528\ \text{rad/s}^2}$.

21. (a) $D = (70)(2\pi r)$ = 220 m. Use eq (2–10c). $(13.9)^2 = (25)^2 + 2a(220)$. a = −0.981 m/s2.
Hence $\alpha = a/r$ = $\underline{-2.0\ \text{rad/s}^2}$.

(b) Use eq (2–10a). 0 = (13.9) + (−0.981)t. $\underline{t = 14\ \text{s}}$.

22. (a) $a_T = r\alpha$, $a_c = r\alpha^2 t^2$.

(b) $\phi = \arctan(1/\alpha t^2)$ but $\theta = \alpha t^2/2$, $\alpha t^2 = 4\pi N$. Hence ϕ = $\underline{\arctan(1/4\pi N)}$.

23. (60 kg)(9.8 m/s²)(0.18 m) = $\underline{106\ \text{N}\cdot\text{m}}$.

24. (a) (28)(0.84) = $\underline{23.5\ \text{Nm}}$

(b) (28)(0.84)(sin 60°) = $\underline{20.4\ \text{Nm}}$

25. Clockwise Torque = (20)(0.2) + (35)(0.1) − (30)(0.2) = 1.5 Nm.
Net Torque = 1.5 − 0.3 = 1.2 Nm, clockwise.

26. $F = T/L = 90/0.2 = 450$ N.
$T = 6\,fl$
$f = \dfrac{T}{6l} = 90/6/0.0075 = 2000$ N.

27. $I = (2/5)MR^2 = (0.4)(22)(0.806)^2 = 5.72$ kg m²

28. $(1.25)(0.3335)^2 = 0.139$ kg m². Because hub radius of gyration is so small.

29. $I = Mr^2 \quad r = \sqrt{\dfrac{I}{M}} \quad d = 2\sqrt{\dfrac{I}{M}} = 2[(1.9 \times 10^{-46})/(5.3 \times 10^{-26})]^{\frac{1}{2}} = 1.20 \times 10^{-10}$ m

30. (a) $(1.25)(1.2)^2 = 1.8$ kg m²

(b) $T = (0.02)(1.2) = 0.024$ Nm.

31. (a) $(0.88)(0.125)^2/2 = 6.88 \times 10^{-3}$ kg m²

(b) $\alpha = \omega/t = 126/4 = 31.4$ rad/s. Use eq (8–14)
$t = 0.0145 + (31.4)(6.88 \times 10^{-3}) = 0.230$ Nm.

32. $\alpha = \omega/t = (62.8)/10 = 6.28$ rad/s. But using eq (8–14), $k = (3.25/6.28/23.6)^{\frac{1}{2}} = 0.148$ m

33. $\alpha = 2\theta/t^2 = 2(2\pi\ 180)/15^2 = 10.05$ rad/s².
$I = 25/10.05 = 24.9$ kg m² $= (2/5)M(0.6)^2$.
Hence $M = 17$ kg.

34. $\alpha = \omega/t = (16$ rad/s$)/(9$ s$) = 1.78$ rad/s². $I = (31{,}000$ kg$)(8$ m$)^2/2 = 9.92 \times 10^5$ kg . m².
Torque $= I\alpha = 1.77 \times 10^6$ Nm.

35. $\alpha = -1.2/4.8/(0.071)^2 = -49.6$ rad/s². Use eq (8–9c). $\theta = (1047)^2/2/49.6 = 11050$ rad
Hence N = $\theta/2\pi$ = 1760 revolutions.
$t = (\omega - \omega_0)/\alpha = -\omega_0/\alpha = -[(10^4 \text{ r.p.m.})(2\pi/60 \text{ s/m})]/(-49.6) = \underline{21.1 \text{ s}}$.

36. $\alpha = a/r = 7/0.3 = 23.3$ rad/s²
$I = (3.6)(0.3)^2 = 0.324$ kg m².

(a) $\tau = I\alpha = \underline{7.55 \text{ Nm}}$.

(b) $F = 7.55/0.025 = \underline{302 \text{ N}}$.

37. (a) $\alpha = a/r = v/(rt) = (10 \text{ m/s})/(0.3 \text{ m})/(0.22 \text{ s}) = \underline{152 \text{ rad/s}^2}$.

(b) $I = (1 \text{ kg})(0.3 \text{ m})^2 + (3.2 \text{ kg})(0.3 \text{ m})^2/3 = 0.186 \text{ kg} \cdot \text{m}^2$.
$F = I\alpha/d = (0.186 \text{ kg} \cdot \text{m}^2)(152 \text{ rad/s}^2)/(0.025 \text{ m}) = \underline{1130 \text{ N}}$.

38. $T_1 - m_1g = m_1a$. $a = R_0\alpha = (T_2 - T_1)R_0^2/I$. $m_2g - T_2 = m_2a$.

Hence $a = \underline{(m_2 - m_1)g(R_0^2/I)/[1 + (m_2 + m_1)R_0^2/I]} = \underline{\dfrac{(m_2 - m_1)g}{m_1 + m_2 + \dfrac{I}{R_0^2}}}$

If $I = 0$, $a = \underline{(m_2 - m_1)g/(m_2 + m_1)}$.

39. (a) $\alpha = \omega^2/2\theta = (27.2 \text{ m/s}/2.10 \text{ m})^2/2/4/2\pi = \underline{3.34 \text{ rad/s}^2}$.

(b) $a_T = r\alpha = (2.10 \text{ m})(3.34 \text{ rad/s}^2) = \underline{7.01 \text{ m/s}^2}$.

(c) $a_c = v^2/r = (27.2 \text{ m/s})^2/2.10 \text{ m} = \underline{352 \text{ m/s}^2}$.

(d) $a = (a_T^2 + a_c^2)^{\frac{1}{2}} = 352 \text{ m/s}^2$. $F = ma = (7.3 \text{ kg})(352 \text{ m/s}^2) = \underline{2.57 \times 10^3 \text{ N}}$.

(e) $\theta = \arctan(a_T/a_c) = \underline{1.14°}$.

40. $E = I\omega^2/2 = (4 \times 10^{-2} \text{ kg} \cdot \text{m}^2)(1047 \text{ rad/s})^2/2 = \underline{2.19 \times 10^4 \text{ J}}$.

41. $mgh = mv^2/2 + I\omega^2/2 = mv^2/2 + mv^2/4$; where we have used $v = r\omega$, $I = mr^2/2$;

$v = (4\,gh/3)^{\frac{1}{2}} = \underline{12.0 \text{ m/s}}$.

42. (a) $I = (2/5)MR^2 = 9.8 \times 10^{37}$ kg m². $\omega = 2\pi/86\ 400 = 7.27 \times 10^{-5}$ rad/s.
$KE = 0.5\ I\omega^2 = \underline{2.59 \times 10^{29}\ \text{J}}$

(b) $\omega = 2\pi/(3.16 \times 10^7) = 2 \times 10^{-7}$ rad/s.
$KE = 0.5(6 \times 10^{24})(1.5 \times 10^{11})^2(2 \times 10^{-7})^2 = \underline{2.7 \times 10^{33}\ \text{J}}$

43. $I = Mk^2 = (1860\ \text{kg})(18.5\ \text{m})^2 = 6.37 \times 10^5\ \text{kg}\cdot\text{m}^2$
$\omega = 2\pi/(7.10\ \text{s}) = 0.885$ rad/s

$$\text{Work} = \Delta kE = \frac{1}{2}(6.37 \times 10^5\ \text{kg}\cdot\text{m}^2)(0.885\ \text{rad/s})^2 - 0 = \underline{2.49 \times 10^5\ \text{J}}$$

44. (a) 100 km/h = 27.8 m/s
$I = Mr^2 = (30\ \text{kg})(0.30\ \text{m})^2 = 2.7\ \text{kg}\cdot\text{m}^2$
$\omega = v/r = (27.8\ \text{m/s})/(0.40\ \text{m}) = 69.4$ rad/s

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}(1200\ \text{kg})(27.8\ \text{rad/s})^2 + \frac{1}{2}(4)(2.7\ \text{kg}\cdot\text{m}^2)(69.4\ \text{rad/s}^2) = \underline{4.9 \times 10^5\ \text{J}}$$

(b) $\text{Frac} = \frac{1}{2}(2.7\ \text{kg}\cdot\text{m}^2)(69.4\ \text{rad/s})^2/(4.67 \times 10^5\ \text{J}) = \underline{0.0139}$

(c) $F = ma$ for body of car
$\tau = FR = I\alpha$ for wheels
$\alpha = a/R$
So $F = I(a/R)/R = Ia/R^2$
So $F = ma + Ia/R^2 = (m + I/R^2)a$
$2000\ \text{N} = [(1200\ \text{kg}) + 4(2.7\ \text{kg}\cdot\text{m}^2)/(0.40\ \text{m}^2)]a$
$a = \underline{1.58\ \text{m/s}^2} = \underline{1.6\ \text{m/s}^2}$

(d) $F = ma$
$2000\ \text{N} = (1200\ \text{kg})a$
$a = 1.66667\ \text{m/s}^2$
% error = (1.67 – 1.58)/1.58 × 100% = <u>5.7%</u>

45. Energy conservation gives $m_2gh = \frac{1}{2}I\omega^2 + \frac{1}{2}(m_1 + m_2)v^2 + m_1gh.$
$I = Mr^2/2$, $\omega = v/r$. $V^2 = (m_2 - m_1)gh/[M/4 + (m_1 + m_2)/2]$. $v = \underline{2.95\ \text{m/s}}$.

46. $mgh = mg(L/2) = I\omega^2/2 = (m\ell^2/3)(v/\ell)^2/2$, i.e. $v^2 = 3\ g\ell$. $v = \underline{12.2\ \text{m/s}}$.

47. $L = I\omega = (0.2\ \text{kg})(1\ \text{m})^2(9.45\ \text{rad/s}) = \underline{(1.89)\text{kg}\ .\ \text{m}^2/\text{s}}$.

48. (a) L is conserved; if I increases ω decreases. Note no need to change units.
$I_1\omega_1 = I_2\omega_2$. $I_1(1.20 \text{ rev/s}) = I_2(0.80 \text{ rev/s})$. $I_2 = \underline{1.5\ I_1}$.

49. As L is conserved, $I_1(2 \text{ rev}/1.5 \text{ s}) = 3.5\ I_1 f$. Hence $f = \underline{0.38 \text{ rev/s}}$.

50. (a) $I = \frac{2}{5}MR^2 = (0.4)(6.0 \times 10^{24} \text{ kg})(6.4 \times 10^6 \text{ m})^2 = 9.83 \times 10^{37} \text{ kg}\cdot\text{m}$
$\omega = 2\pi/T = 2\pi/86\,400 \text{ s} = 7.27 \times 10^{-5} \text{ rad/s}$
$L = I\omega = (9.83 \times 10^{37} \text{ kg}\cdot\text{m}^2)(7.27 \times 10^{-5} \text{ rad/s}) = \underline{7.15 \times 10^{33} \text{ kg}\cdot\text{m}^2\text{/s}}$
(b) $I = MR^2 = (6.0 \times 10^{24} \text{ kg})(1.5 \times 10^{11} \text{ m})^2 = 1.35 \times 10^{47} \text{ kg}\cdot\text{m}^2$
$\omega = 2\pi/T = 2\pi/(365)/(86\,400 \text{ s}) = 1.99 \times 10^{-7} \text{ rad/s}$
$L = I\omega = (1.35 \times 10^{27} \text{ kg}\cdot\text{m}^2)(1.99 \times 10^{-7} \text{ rad/s}) = \underline{2.69 \times 10^{40} \text{ kg}\cdot\text{m}^2\text{/s}}$

51. (a) $L = I\omega = [(2.43)(0.125)^2/2](168) = 3.18 \text{ kg . m}^2\text{/s}$

(b) $\tau = L/t = 3.18/8 = \underline{0.398 \text{ N . m}}$.

52. $L = I\omega_i = I\omega_p + I\omega_f$
$\omega_f = \underline{\omega_i/2}$

53. $I_{disk} = \frac{1}{2}MR^2$

$I_{rod} = \frac{1}{12}M(2R)^2 = \frac{1}{3}MR^2$

$I_{tot} = \frac{5}{6}MR^2$

$L = \left[\frac{1}{2}MR^2\right](8.0 \text{ rev/s}) = \left[\frac{5}{6}MR^2\right]\omega_f$

$\omega_f = \underline{4.8 \text{ rev/s}}$

54. Angular momentum = $(1750)(0.8) + 0 = [(1750) + 4(65)(2.25)^2]\omega$. Hence $\omega = \underline{0.457 \text{ rad/s}}$.
<u>No change</u> in the angular velocity of merry-go-round; angular momentum of people is destroyed by frictional torque from the earth upon landing.

55. Let us define Ω and $-\omega$ as the final angular velocities with relation to the earth of the turntable and the man. Then conservation of angular momentum gives $[1800 \text{ kg . m}^2)\Omega = (60 \text{ kg})(9 \text{ m}^2)\omega$, i.e. $3.33\ \Omega = \omega$. We know that $(3 \text{ m})(\Omega + \omega) = 4.2 \text{ m/s}$, i.e. $\Omega = \underline{0.32 \text{ rad/s}}$.

56. In this problem unless the wheel is <u>touched</u> its ω_W has the same magnitude with relation to . ... no matter how it is manouvered. Secondly there can be no external torque about the vertical . through the center of the turntable, i.e. vertical angular momentum is zero throughout.

(a) $I_p\omega_p + I_w\omega_w = 0$; $\omega_p = -\omega_w(I_w/I_p)$.

(b) $I_p\omega_p + I_w\omega_w \cos 60^\circ = 0$; $\omega_p = -\omega_w(I_w/2\ I_p)$.

(c) $\omega_p = \omega_w(I_w/I_p)$.

(d) zero.

57. Horizontal pseudoforce $= r\omega^2$
Vertical force $= mg$.
Angle $=$ <u>$\tan^{-1}(r\omega^2/mg)$</u> from vertical.
Inward because pseudoforce is outward, and plant opposes "gravity"

$$\tan\,\theta = \frac{r\omega^2}{g}$$

58. In a rotating coordinate system fixed with the rotating object the problem is a purely static one. Newton's third law is still applicable, but some of the forces are fictitious ones, not seen by the inertial observer.

59. (a) Initially the ball has a greater tangential velocity than the person at A. When the ball reaches a distance r_A from the center, the observer A owing to its smaller initial tangential velocity is still behind. The person at A will see the ball ahead of him.

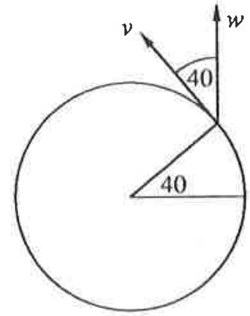
(b) If v is the velocity of the ball, the ball moves a distance $(r_b - r_a) = Ut$
A moves sideways, $s_A = v_A t$
Ball moves sideways, $s_B = v_B t$
Sideways deflection(s) $= (v_B - v_A)t = (r_B\omega - r_A\omega)t$
(s) $= (r_B - r_A)\omega t$
$s = (vt)\omega t$
$s = v\omega t^2$

Compare $s = \frac{1}{2}a_c t^2 \Rightarrow a_c = 2\omega v$

60. (a) $v_\perp = v\cos\lambda$. Thus $a_{cor} = 2wv_\perp = 2w(v\cos\lambda)$.

(b) Since direction of velocity component perpendicular to earth's axis is toward rotation axis, the object "passes in front of target." i.e. eastward, since earth is rotating toward east.

61. Coriolis force depends on velocity component perpendicular to rotation axis. Thus an object moving parallel to the axis is unaffected, i.e. North or South at the equator.



62. north; south 500 km/h = 139 m/s
Component of velocity perpendicular to Earth's axis is
$v_\perp = (139\text{ m/s})\sin(40°)$
$v_\perp = 89.3\text{ m/s}$
$\omega = 2\pi/T = 2\pi/(86\,400\text{ s}) = 7.27 \times 10^{-5}\text{ rad/s}$
$a_c = 2\omega v = 2(7.27 \times 10^{-5}\text{ rad/s})(89.3\text{ m/s}) = 0.0130\text{ m/s}^2$
$F_c = ma_c = (1200\text{ kg})(0.0130\text{ m/s}^2) = \underline{15.6\text{ N}}$

63. Assume spool diameter is same as inner cylinder on which rope is wrapped. Then if spool is moving with speed v at center, and rotating with speed ω because it is not slipping the bottom is instantly at rest, i.e. $0 = v - r\omega$. The middle moves with the speed $r\omega$. The top with speed $v + r\omega = 2r\omega$. To keep rope tight man moves with speed $2r\omega$, the spool with speed $r\omega$. Thus distance between man and spool is $\underline{L/2}$. The spool moves $\underline{L/2}$.

64. Point at top rim accelerates at $a = 1.50\text{ m/s}^2$
$v = v_0 + at = (0\text{ m/s}) + (1.50\text{ m/s}^2)(3.0\text{ s}) = \underline{4.50\text{ m/s}}$

65. The moon turns around on its axis every 28 days and turns around the earth in the same time. Thus $L_{spin}/L_{rot} = (2/5)(1.74 \times 10^6\text{ m})^2/(3.84 \times 10^8\text{ m})^2 = \underline{8.21 \times 10^{-6}}$.

66. $I_0\omega_0 = I\omega$, i.e. $\omega = \omega_0(I_0/I) = \omega_0(0.4\ MR_0^2/0.4\ MR^2) = \omega_0(R_0/R)^2$
$(1\text{ rev/10 days})(7 \times 10^5\text{ km/10 km})^2 = 4.9 \times 10^8\text{ rev/day} = \underline{5.67 \times 10^3\text{ rev/s}}$.

67. Train has $\omega = v/r$. Turntable has $\omega = -v/r$.
By conservation of momentum $(MR^2/2)(-v/R) + (mR^2)(v/R) = 0$. Hence $m = M/2$.

68. (a) Energy spent is $(500\text{ N})(3 \times 10^5\text{ m}) + 20(0.5)(1400\text{ kg})(25\text{ m/s})^2 = \underline{1.59 \times 10^8\text{ J}}$.

(b) $\omega^2 = (2\ E/I) = 2(1.59 \times 10^8\text{ J})/(240\text{ kg})/(0.75\text{ m})^2/(0.5)$; $\omega = \underline{2.17 \times 10^3\text{ rad/s}}$.

(c) Time $= (1.59 \times 10^8\text{ J})/(150\text{ hp})/(746\text{ W/hp})/(60\text{ s/min}) = \underline{23.5\text{ min}}$.

69. From the conservation of energy, $mgh = \frac{mv^2}{2} + \frac{1}{2}I\omega^2$ using $v = r\omega$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}(mr^2)\left[\frac{v^2}{r^2}\right]$$
$$mgh = mv^2$$
$$gh = v^2$$

$h = L \sin 20.$
$gh = v^2$
$(g)(L \sin 20) = (5.2 \text{ m/s})^2$

$$L = \frac{(5.2 \text{ m/s})^2}{g \sin 20} = 8.1 \text{ m.}$$

(b) Using 2–10c
$0 = (5.2 \text{ m/s})^2 + (2a)(8.06 \text{ m})$
$a = -1.67 \text{ m/s}^2$
using 2–10a
$0 = (5.2 \text{ m/s}) - (1.67 \text{ m/s}^2)t$
$t = 3.11$ s
Total time on plane $= 2t = 6.2$ s.

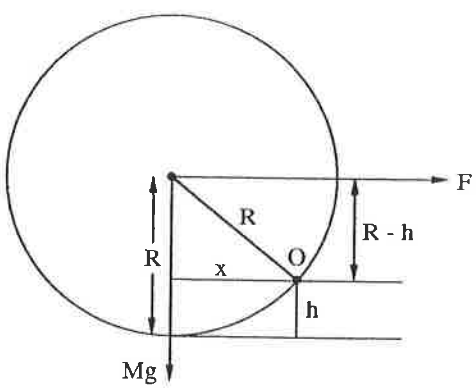
70. (a) $I = \frac{1}{3}ML^2$

$$\tau = Fr = Mg\left[\frac{L}{2}\right]$$

$\alpha = \tau/I = (MgL/2)/(ML^2/3) = \underline{(3g/2L)}$

(b) $a_t = L\alpha = L(3g/2L) = 3g/2 = 3(9.80 \text{ m/s}^2)/2 = \underline{14.7 \text{ m/s}^2}$

71.



0 is the point of rotation. F must overcome torque due to weight.
$x^2 = R^2 - (R - h)^2 = R^2 - (R^2 + h^2 - 2Rh)$
$Mgx = F(R - h)$

$$F = \frac{mgx}{(R - h)} = \frac{mg\sqrt{(2Rh - h^2)}}{R - h}$$

$$F = \frac{mg\sqrt{(2Rh - h^2)}}{(R - h)}$$

72. There is no angular acceleration of bicycle about a line through cm parallel to velocity vector. Hence torque is zero, i.e. $F_N \sin\theta\, d = F_{fr} \cos\theta\, d$. $\tan\theta = F_{fr}/F_N$. (Note $F_{fr}/F_N = \mu$, so $\tan\theta = \mu$)

(b) $F_{fr} = mv^2/r$ for circular motion; $\tan\theta = v^2/rg$; $\theta = \arctan[(5.4\text{ m/s})^2/(4.9\text{ m})(9.8\text{ m/s}^2)] = \underline{31°}$.

(c) $\tan\theta = (\mu mg/mg) = 0.65 = (5.4\text{ m/s})^2/r(9.8\text{ m/s}^2)$. Hence $r = 4.58\text{ m} = \underline{4.6\text{ m}}$.

73. (a) $W = Fd = Fr\Delta\theta = T\Delta\theta$.

(b) $P = Fv = Fr\omega = T\omega$.

(c) $P = (280\text{ N . m})(419\text{ rad/s})/(750\text{ W/hp}) = \underline{157\text{ hp}}$.

74. $mgh = \frac{1}{2}mv^2 + \frac{1}{2}\left[\frac{2}{5}mr^2\right]\left[\frac{v}{r}\right]^2 + mg(2R_0)$

$gh = \frac{7}{10}v^2 + 2gR_0$

At top, $v^2/R_0 = g$, so $v^2 = R_0 g$

$gh = \frac{7}{10}(R_0 g) + 2R_0 g$

$h = \underline{2.7\,R_0}$

75. $mg(h + r) = \frac{1}{2}mv^2 + \frac{1}{2}\left[\frac{2}{5}mr^2\right]\left[\frac{v}{r}\right]^2 + mg(2R_0 - r)$

$g(h + r) = \frac{7}{10}v^2 + g(2R_0 - r)$

At top, $v^2/(R_0 - r) = g$, so $v^2 = g(R_0 - r)$

$(h + r) = \frac{7}{10}(R_0 - r) + (2R_0 - r)$

$h = 2.7\,R_0 - 1.7r - r$

$h = \underline{2.7(R_0 - r)}$

76. $Mg(L/2) = \frac{1}{2}Mv^2 + \frac{1}{2}\left[\frac{1}{12}ML^2\right]\omega^2$

But $\omega = v/(L/2) = 2v/L$

$MgL/2 = \frac{1}{2}Mv^2 + \frac{1}{24}ML^2(2v/L)^2 = \frac{1}{2}Mv^2 + \frac{1}{6}Mv^2$

$MgL/2 = \frac{2}{3}Mv^2$

$\underline{v = (3/4\;gL)^{\frac{1}{2}}}$

Chapter 9

1. $2T(\cos 80^\circ) = 0.50$ N. $T = \underline{1.44 \text{ N}}$

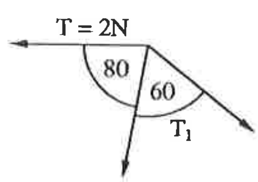
2. $T = mgd = (70)(9.8)(3) = \underline{2.06 \times 10^3 \text{ Nm}}$

3. $m = (Tl)/(gl') = (12)(9.8)(0.36)/0.805/9.8 = \underline{5.37 \text{ kg}}$

4. $F_1 \cos 45^\circ = F_2$. Therefore F_1 is the bigger. $F_1 = 1200$ N. $1200 \sin 45^\circ = W = \underline{848 \text{ N}}$.

5. About end near piano, $(200)g(L/4) + (180)g(L/2) - F_N L = 0$.
F_N = vertical force on a far end = $(140)(g) = \underline{1370 \text{ N}}$.
Vertical force on near end = $200g + 180g - 140g = 240g = \underline{2350 \text{ N}}$

6.



Resolve and balance forces perpendicular to desired re nt.
$(2 \text{ N})(\sin 80^\circ) = T_1 \sin 60^\circ$. $T_1 = \underline{2.27 \text{ N}}$.

7. Resolve and balance forces perpendicular to each string.
$T_R = (30 \text{ kg})(9.8 \text{ m/s}^2)(\cos 45^\circ)/(\sin 98^\circ) = \underline{210 \text{ N}}$.
$T_L = (30 \text{ kg})(9.8 \text{ m/s}^2)(\cos 37^\circ)/(\sin 98^\circ) = \underline{240 \text{ N}}$.

8. $(20 + 25 + 30)(9.8) = 735$ N

9. $\Sigma\tau = F_2(20 \text{ m}) - mg(25 \text{ m}) = 0$.
$F_2 = mg(25 \text{ m})/20 \text{ m}$.
Torques about the left end: $F_2 = (1200 \text{ kg})(9.8 \text{ m/s}^2)(25 \text{ m})/(20 \text{ m}) = \underline{1.47 \times 10^4 \text{ N}}$.
Torques about right support $F_1 = (1200 \text{ kg})(9.8 \text{ m/s}^2)(5 \text{ m})/20 \text{ m} = \underline{2.94 \times 10^3 \text{ N}}$.
Check: $F_1 + F_2 - mg = 0$.